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LABORATORY TESTS ON THE DURABILITY OF AMERICAN WOODS—I.

FLASK TESTS ON CONIFERS

C. J. Humphrey

(With Plate 183)

Introduction

Our present knowledge of the relative durability of American woods has been, for the most part, derived from service or field tests carried out by engineers or agriculturalists. Certain of the larger wood users, such as railroads, telephone and telegraph companies, have for several years past kept records on the durability of ties, poles and other timbers as a basis for the selection of durable material or for determining the expediency of applying wood preservatives. Similar data have been secured through the experimental work of the United States Forest Service and the Agricultural Experiment Stations.

The conditions governing such tests can not be kept uniform or in any way put under control. Hence, even for a single species of timber, the data secured will be highly variable, depending upon the character of the soil, drainage, air and soil temperature, precipitation, atmospheric humidity, and any other factors which may influence the growth of wood-rotting fungi. Since environmental factors offer great variations between different regions of the United States, we can readily see why the natural durability of timber in warm, humid regions, for instance, frequently falls short of its resistance to decay in cooler, less moist localities.

The question of the presence or absence of certain of the more destructive species of fungi in a given locality also influences natural durability. In regions long free of forests the soil may, for instance, be comparatively free of wood-rotting fungi. The relative great abundance of decay-producing species and individuals in the tropics is one factor in the rapid deterioration of timber in those regions. It is but Nature's way in maintaining the proper balance in plant life, for where trees develop luxuriantly they must also rot rapidly.

The manner and rate at which different species of fungi act on given kinds of wood is often highly variable, more or less a specific property of the fungus. Under natural conditions certain species seem exclusively or predominantly to attack conifers, while others confine their activities to hardwood (broadleaf) timber. Still others may attack almost exclusively hardwood trees in one region and conifers in another. In some cases this may be an apparent rather than a real condition, however, since our judgment as to the identity of a fungus rests upon the morphological characters of the fruit-bodies which it produces and it is an oft-observed fact that many decaying timbers fail to develop the fruiting stage of the organism at all.

LABORATORY TESTS ON DURABILITY

Comparatively few laboratory tests on the durability of timber are recorded either in European or American literature. The European continent, however, has few timber species compared with the great variety on the American side.

Through the activities of the United States Forest Service strength values and other physical properties of our commercial woods have been worked out, but this paper is the first of a series on the relative resistance which the different timbers offer toward different fungi. It is proposed to carry on the work from year to year, using various wood-rotting fungi and adding new kinds of timber as they are made available.

The work was begun about three years ago at the Forest Products Laboratory on material collected from all portions of the United States primarily for timber test purposes. Both heartwood and sapwood were secured whenever possible, but since the available material comprised in many cases only corners and slabs remaining after sawing out the specimens for strength tests it was not always possible to get everything desired. In the case of hemlocks, firs and spruces heartwood and sapwood are poorly differentiated as far as color changes go, the differences in physiological functions in the living trees, however, are just as marked as in other species of timber. Wood classed as heartwood was always selected well within the sapwood ring.

The present paper comprises tests on 28 species of conifers and presents data only on single specimens of wood for three different test periods. As it consists in but one set of tests the figures should be considered as preliminary and indicative rather than final. Other tests now under way will throw further light on the question and when sufficient data have accumulated generalizations will become admissable. Due consideration to these facts should be given in interpreting durability values. Also, the fact that different samples of the same kind of wood show different durabilities, depending upon their physical, and possibly chemical, constitution must be kept in mind in establishing a true conception of the resistance which the woods offer to decay.

The very destructive and vigorous-growing fungus, *Lentinus lepideus* Fr., which is abundantly distributed on coniferous timber over practically the entire United States, was selected for this first series of tests on account of its very rapid growth and the vigor with which it is known to rot many species of conifers in nature. The culture was secured from a tissue transfer taken from a plant collected by the writer from a Douglas fir stump in Montana in 1910. The purity of the culture is unquestioned; it has produced typical, but, of course, reduced, fruit-bodies several times during the course of the tests (*Plate 183.*)

METHOD

All tests have been conducted in 2-liter Erlenmeyer flasks, plugged rather tightly with absorbent cotton, and then capped with thin muslin soaked in a dilute solution of mercuric chloride.

The flasks were prepared in triplicate, the original intention being to examine the first at the end of three months, the second after six months, and the third after nine months. Field work interrupted this schedule somewhat, as noted by the tables.

The test woods were identified and the logs marked with a stencil or paint in the forest by the various collectors. They were then shipped to the laboratory in a green condition and sawn as needed. The blocks for durability tests were cut ⅝ by ⅝ inch square and 2 inches long from clear material, free of defects. In selecting heart and sapwood close attention was paid to getting representative material. In order to determine the actual loss in weight from decay, the blocks were dried in a steam-heated oven for 48 hours at a temperature of 100° C., or close around that point, and then weighed to the nearest .01 of a gram. On the completion of the tests the blocks were again oven-dried in a similar manner, the resulting weights compared with the original, and the percentage loss, based on the dry weight of the sound material calculated.

The flasks in which the experiments were carried out were prepared as follows: Culture blocks[1] from 1 to 2 inches long and of a diameter sufficient to go through the neck of a wide-mouth flask were cut from hemlock, boiled to saturation in tap water, and given a preliminary sterilization of several hours at about 10 pounds pressure in the autoclave. This was for the purpose of killing any latent fungi and of removing the excess water. On removing from the autoclave a layer of these blocks was placed in the bottom of each flask, resting on a layer of absorbent cotton[2] saturated with water. The test blocks, usually ten different species to a flask, were then inserted in a dry condition, taking care to keep them well off the wet cotton. Another layer of hemlock culture blocks was then added to about three-fourths of the height of the flask, this being surmounted by another wad of saturated absorbent cotton. The flasks were then tightly plugged with cotton and sterilized in the autoclave, without pressure, for periods of 45, 30, and 30 minutes, respectively, on three successive days.

After sterilization they were inoculated with a culture of *Lentinus lepideus,* growing on a bean pod, by emptying the bean directly into the flask. When inoculating wood cultures it is quite essential to use a generous quantity of infecting material.

The test blocks were grouped more or less according to their supposed durability, heartwood and sapwood samples in every

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[1] The term "culture blocks" refers to the irregular hemlock blocks introduced into the flasks as a medium to support a vigorous growth of the fungus in order to secure a uniform and severe infection of the "test blocks."

[2] In later work the cotton has been omitted, as the test blocks often became too wet.

TABLE I

DURABILITY OF SAPWOOD AFTER 4 MONTHS' TEST[3]

[An asterisk (*) denotes that the blocks became too wet for a fair test.]

Kind of Wood	Flask No.	Oven-Dry Weight (Grams)		Loss		Remarks
		Before Test	After Test	Grams	Per Cent.	
Eastern hemlock	1	6.44	5.25	1.19	18.5	Considerably rotted.
Mountain hemlock	1	7.39	7.07	0.32	4.3*	
Western hemlock	4	7.87	5.67	2.20	28.0	Seriously rotted.
Engelmann spruce	4	6.35	4.51	1.84	29.0	Seriously rotted.
Sitka spruce	4	5.49	4.61	0.88	14.2*	
Red spruce	4	6.79	4.98	1.81	26.7	Rotted at ends.
White spruce	4	6.25	4.51	1.74	27.8	Seriously rotted.
Alpine fir	4	6.19	4.76	1.43	23.1	Seriously rotted.
Grand fir	4	7.30	6.90	0.4	5.5*	
Grand fir	4	5.98	4.58	1.40	23.4	Seriously rotted.
Noble fir	4	6.73	5.05	1.68	25.0	Seriously rotted.
Douglas fir	7	7.36	5.42	1.94	26.4	Seriously rotted.
European larch	4	7.16	6.44	0.72	10.0*	
Western yellow pine	1	6.65	5.03	1.62	24.4	Seriously rotted.
Lodgepole pine	1	6.80	5.37	1.43	21.0	Seriously rotted.
Longleaf pine	7	7.93	5.51	2.42	30.5	Seriously rotted.
Shortleaf pine	7	8.46	6.34	2.12	25.1	Seriously rotted in springwood.
Table mountain pine	1	7.33	6.69	0.64	8.7*	
Pitch pine	1	8.65	6.55	2.10	24.3	Seriously rotted.
White pine	1	4.12	3.06	1.06	25.7	Seriously rotted.
Sugar pine	1	5.11	3.94	1.17	22.9	Seriously rotted.
Western white pine	1	6.40	5.30	1.10	17.2	Considerably rotted.
White cedar	7	4.52	4.50	0.02	.. *	
Western red cedar	7	4.76	4.65	0.11	2.3*	
Port Orford cedar	7	6.52	5.23	1.29	19.8	Seriously rotted on three sides.
California juniper	7	9.50	6.81	2.69	28.3	Seriously rotted.
Western juniper	7	6.77	5.30	1.47	21.7	Seriously rotted.
Bigtree	7	7.94	7.72	0.22	2.8*	

case being tested in separate flasks. Each block was marked by writing its name and number on two faces with a soft heavy-leaded pencil. This system of marking has proven satisfactory and has been adopted for all work of this nature.

The flasks were inoculated on January 29, 1914. In about a month the contents were uniformly infected throughout. Flasks 11, 12, and 17, becoming contaminated with molds, were opened, the test blocks again oven-dried for 24 hours and new culture flasks prepared as before. All cultures were then kept in a glass case in the diffuse light of the laboratory. The temperature fluc-

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[3] Data in this table and the following are based on single specimens of each sample of wood.

TABLE II

DURABILITY OF HEARTWOOD AFTER 4 MONTHS' TEST

[An asterisk (*) denotes that the blocks became too wet for a fair test.]

Kind of Wood	Flask No.	Oven-Dry Weight (Grams)		Loss		Remarks
		Before Test	After Test	Grams	Per Cent.	
Eastern hemlock......	16	7.75	6.12	1.63	21.0	Considerably rotted.
Mountain hemlock....	16	8.25	4.90	3.35	40.6	Seriously rotted.
Western hemlock......	13	7.19	5.31	1.88	26.1	Seriously rotted.
Engelmann spruce.....	13	7.10	3.65	3.45	48.6	Friable when dry.
Sitka spruce..........	13	6.81	4.43	2.38	34.9	Seriously rotted.
Red spruce...........	13	6.89	4.80	2.09	30.3	Seriously rotted.
White spruce.........	13	6.20	4.11	2.09	33.7	Seriously rotted.
Alpine fir.............	13	6.22	3.73	2.49	40.0	Friable when dry.
Grand fir.............	13	7.23	5.04	2.19	30.3	Friable when dry.
Grand fir.............	13	5.93	2.79	3.14	53.0	Friable when dry.
Noble fir.............	13	7.44	5.11	2.33	31.3	Seriously rotted.
Douglas fir...........	10	7.12	4.73	2.39	33.6	Seriously rotted.
European larch........	13	7.23	4.18	3.05	42.2	Seriously rotted.
Western yellow pine...	16	7.11	5.84	1.27	17.9	Considerably rotted.
Lodgepole pine........	16	6.74	5.75	0.99	14.7*	Considerably rotted.
Longleaf pine.........	10	10.62	10.58	0.04	0.4	Sound.
Shortleaf pine.........	10	11.51	10.70	0.81	7.0	Slightly rotted in springwood.
Table mountain pine...	16	10.50	10.12	0.38	3.6	Slightly affected.
Pitch pine............	16	10.69	10.44	0.25	2.3*	
Norway pine..........	16	8.02	8.02	0	0 *	
White pine...........	16	6.57	6.50	0.07	1.1*	
Sugar pine............	16	5.95	5.10	0.85	14.3*	
Western white pine....	16	7.14	6.45	0.69	9.7*	Considerably rotted.
White cedar..........	10	5.07	5.10	0	0	Sound.
Western red cedar.....	10	5.06	5.04	0.02	0.4*	
Port Orford cedar.....	10	7.15	7.06	0.09	1.3*	
California juniper.....	10	9.88	9.90	0	0	Sound.
Western juniper.......	10	6.15	6.11	0.04	0.7*	
Bigtree..............	10	8.10	8.04	0.06	0.7	Sound.

tuated considerably with the seasonal variations, usually around 20° C. in the winter and running up to 25 to 30° C. during the warm summer months.

Eighteen flasks in all were prepared. Flasks 1, 4, 7, 10, 13, and 16 were opened and examined on May 24, 1914, four months after inoculation; flasks 2, 5, 8, and 14 were opened on August 4, after six months' test; flasks 3, 6, 9, 15, and 18 after twelve months; flasks 11, 12, and 17, which were remade and inoculated on March 24, 1914, were examined on the same date the following year.

In computing the actual period of test it should be kept in mind that from three to four weeks are required to get a uniform infection after the inoculations are made. In the following tables,

TABLE III

DURABILITY OF SAPWOOD AFTER 6 MONTHS' TEST

[An asterisk (*) denotes that the blocks became too wet for a fair test.]

Kind of Wood	Flask No.	Oven-Dry Weight (Grams)		Loss		Remarks
		Before Test	After Test	Grams	Per Cent.	
Eastern hemlock	2	6.55	5.46	1.09	16.6*	Rotted at ends.
Mountain hemock	2	7.40	6.13	1.27	17.2*	Rotted at ends.
Western hemlock	5	8.55	7.52	1.03	12.0*	
Engelmann spruce	5	6.11	3.41	2.70	44.2	Well rotted.
Sitka spruce	5	5.74	2.68	3.06	53.3	Friable when dry.
Red spruce	5	6.43	3.39	3.04	47.3	Friable when dry.
White spruce	5	6.45	3.21	3.24	50.2	Friable when dry.
Alpine fir	5	6.15	3.40	2.75	44.7	Friable when dry
Grand fir	5	6.57	3.90	2.67	40.6	Well rotted.
Grand fir	5	5.95	3.64	2.31	38.8	Well rotted.
Noble fir	5	6.53	3.80	2.73	41.8	Well rotted.
Douglas fir	8	7.67	3.96	3.71	48.4	Friable when dry.
European larch	5	7.40	3.73	3.67	49.6	Friable when dry.
Western yellow pine	2	7.27	3.45	3.82	52.5	Well rotted.
Lodgepole pine	2	7.10	3.79	3.31	46.6	Well rotted.
Longleaf pine	8	8.78	3.85	4.93	56.1	Friable when dry.
Shortleaf pine	8	7.90	2.79	5.11	64.7	Friable when dry.
Table mountain pine	2	7.80	4.53	3.27	41.9	Well rotted in springwood.
Pitch pine	2	8.92	7.60	1.32	14.8*	
White pine	2	4.20	2.00	2.20	52.4	Friable when dry.
Sugar pine	2	5.11	2.31	2.80	54.8	Friable when dry.
Western white pine	2	8.10	4.45	3.65	45.1	Well rotted.
White cedar	8	4.56	4.07	0.49	10.7	Well rotted on sap side—two-fifths heartwood.
Western red cedar	8	4.86	1.96	2.90	59.7	Friable when dry.
Port Orford cedar	8	6.20	3.85	2.35	37.9	Well rotted at ends.
California juniper	8	9.59	8.44	1.15	12.0*	
Western juniper	8	6.65	3.40	3.25	48.9	Friable when dry.
Bigtree	8	8.39	5.24	3.15	37.5	Well rotted in springwood.

however, the test period is considered as beginning with the date of inoculation.

Tables I to VI present the essential data, giving the loss in weight after the different test intervals, together with notes on the condition of the test blocks.

In Table VII the preceding tables are summarized, averages being given for both the heartwood and sapwood of hemlocks, spruces and firs and for the sapwood of the white and hard pine groups. Where the test blocks were too wet they have been marked by an asterisk and have been excluded from all averages.

TABLE IV

DURABILITY OF HEARTWOOD AFTER 6 MONTHS' TEST

[An asterisk (*) denotes that the blocks became too wet for a fair test.]

Kind of Wood	Flask No.	Oven-Dry Weight (Grams)		Loss		Remarks
		Before Test	After Test	Grams	Per Cent.	
Western hemlock	14	7.14	3.30	3.84	53.8	Friable when dry.
Engelmann spruce	14	7.25	3.55	3.70	51.0	Friable when dry.
Sitka spruce	14	6.29	3.60	2.69	42.8	Friable when dry.
Red spruce	14	6.84	2.90	3.94	57.6	Friable when dry.
White spruce	14	6.13	3.20	2.93	47.9	Friable when dry.
Alpine fir	14	6.75	3.55	3.20	47.4	Friable when dry.
Grand fir	14	7.04	3.85	3.19	45.3	Friable when dry.
Grand fir	14	5.65	2.86	2.79	49.4	Friable when dry.
Noble	14	7.87	4.85	3.02	38.4	Friable when dry.
European larch	14	10.04	7.48	2.56	25.5	Well rotted in springwood.

In drawing conclusions from the above data the moisture condition of the test blocks should be given due weight. Such as became obviously too wet for decay to progress at its maximum rate have been indicated, but certain of the other blocks may have varied around their optimum sufficiently to influence the results somewhat. There is a strong indication that certain of the woods vary in their hygroscopic properties, and would thus absorb more moisture in a given time than other woods placed under similar conditions in the same flasks.

In order to assist toward a proper conception of the prevailing moisture condition the records made at the time of opening the flasks are presented as follows:

Flasks 11, 12, 16, and 17 were undeniably too wet. The results on flask 17 have not been used and flasks 11 and 12 have only been employed insofar as they appear of some value in forming a tentative estimate of durability.

In flasks 1, 2, 4, 7, 8, 9, 10, and 18 the moisture conditions were fairly good but rather in excess of the optimum.

Flasks 3, 5, 6, 13, 14, and 15 were in excellent condition, flask 13 apparently being the best of all.

In flask 10 the blocks of white cedar and California juniper were lying close to the top and were only slightly overgrown.

The growth of the fungus was very luxuriant in all and the

TABLE V

DURABILITY OF SAPWOOD AFTER 12 MONTHS' TEST

[An asterisk (*) denotes that the blocks became too wet for a fair test.]

Kind of Wood	Flask No.	Oven-Dry Weight (Grams)		Loss		Remarks
		Before Test	After Test	Grams	Per Cent.	
Eastern hemlock	3	7.40	2.39	5.01	67.7	Friable when dry.
Mountain hemlock	3	8.08	2.47	5.61	69.4	Friable when dry.
Western hemlock	6	7.95	2.41	5.54	69.7	Friable when dry.
Engelmann spruce	6	6.91	2.20	4.71	68.2	Friable when dry.
Sitka spruce	6	5.84	1.84	4.00	68.5	Friable when dry.
Red spruce	6	6.21	2.00	4.21	67.8	Friable when dry.
White spruce	6	7.26	1.78	5.48	75.5	Friable when dry.
Alpine fir	6	5.95	2.05	3.90	65.5	Friable when dry.
Grand fir	6	6.58	2.52	4.06	61.7	Friable when dry.
Grand fir	6	6.37	1.93	4.44	69.7	Friable when dry.
Noble fir	6	6.52	2.04	4.48	68.7	Friable when dry.
Douglas fir	9	7.52	2.37	5.15	68.5	Friable when dry.
European larch	6	7.16	2.11	5.05	70.5	Friable when dry.
Western yellow pine	3	8.18	2.38	5.80	70.9	Friable when dry.
Lodgepole pine	3	7.13	2.30	4.83	67.7	Friable when dry.
Longleaf pine	9	8.13	2.49	5.64	69.4	Friable when dry.
Shortleaf pine	9	9.57	3.00	6.57	68.7	Friable when dry.
Table mountain pine	3	8.00	2.40	5.60	70.0	Friable when dry.
Pitch pine	3	9.60	2.75	6.85	71.4	Friable when dry.
White pine	3	4.75	1.47	3.28	69.1	Friable when dry.
Sugar pine	3	5.18	1.67	3.51	67.8	Friable when dry.
Western white pine	3	8.18	3.15	5.03	61.5	Friable when dry.
White cedar	9	6.63	6.12	0.51	7.7*	Slightly rotted--two-fifths heart.
Western red cedar	9	4.76	3.05	1.71	35.9*	Seriously rotted at ends.
Port Orford cedar	9	6.93	2.30	4.63	66.8	Friable when dry.
California juniper	9	9.30	5.78	3.52	37.9*	Well rotted at ends.
Western juniper	9	7.21	6.00	1.21	16.8*	Considerably rotted.
Bigtree	9	8.38	3.10	5.28	63.0	Friable when dry.

hemlock culture blocks were for the most part thoroughly rotted except as they were too wet, particularly in the bottom of the flasks in contact with the wet cotton.

For the sapwood of 19 species which were in good condition for decay we find an average loss of 24.4 per cent. in 4 months. The average for hemlocks, spruces, and firs (including Douglas fir) was 24.9 per cent. It is thus seen that very little difference exists in the durability of the sapwood of the species tested. An average for the corresponding heartwoods is of no value, on account of the wide differences shown, except for hemlocks, spruces and firs, which average 34.8 per cent. loss. The apparent difference in resistance of heartwood and sapwood in these latter genera, is

TABLE VI

DURABILITY OF HEARTWOOD AFTER 12 MONTHS' TEST

[An asterisk (*) denotes that the blocks became too wet for a fair test.]

Kind of Wood	Flask No.	Oven-Dry Weight (Grams)		Loss		Remarks
		Before Test	After Test	Grams	Per Cent.	
Eastern hemlock	18	7.85	3.17	4.68	59.6	Friable when dry.
Mountain hemlock	18	8.61	3.08	5.53	64.2	Friable when dry.
Western hemlock	15	7.94	3.08	4.86	61.2	Friable when dry.
Engelmann spruce	15	7.23	2.27	4.96	68.6	Friable when dry.
Sitka spruce	15	4.33	1.63	2.70	62.4	Friable when dry.
Red spruce	15	7.07	2.30	4.77	67.5	Friable when dry.
White spruce	15	5.62	1.70	3.92	69.8	Friable when dry.
Grand fir	15	7.10	2.12	4.98	70.1	Friable when dry.
Noble fir	15	7.53	2.25	5.28	70.1	Friable when dry.
Douglas fir	11	7.43	5.34	2.09	28.1*	Seriously rotted at ends.
European larch	15	7.88	4.50	3.38	42.9	Well rotted.
Western yellow pine	18	7.60	3.35	4.25	55.9	Friable when dry.
Lodgepole pine	18	6.93	2.47	4.46	64.4	Friable when dry.
Longleaf pine	12	11.42	5.59	5.83	51.1	Friable when dry.
Shortleaf pine	11	12.25	9.72	2.53	20.7	Seriously rotted in summer wood.
Table mountain pine	18	10.22	6.17	4.05	39.6	Friable when dry.
Pitch pine	18	10.02	8.93	1.09	10.9*	Considerably rotted.
Norway pine	18	8.00	2.45	5.55	69.4	Friable when dry.
White pine	18	6.71	6.12	0.59	8.8	Slightly rotted.
Sugar pine	18	6.06	2.55	3.51	57.9	Friable when dry.
Western white pine	18	7.14	4.85	2.29	32.1*	Well rotted at ends.
White cedar	12	5.40	5.11	0.29	5.4*	Slightly rotted at ends.
Western red cedar	11	5.16	4.06	1.10	21.3*	Seriously rotted at ends.
Port Orford cedar	11	7.81	6.05	1.76	22.6*	Seriously rotted at ends.
California juniper	12	10.66	10.31	0.35	3.3	Slightly affected.
Western juniper	11	5.58	4.73	0.85	15.2*	Seriously rotted ta one end.
Bigtree	11	7.07	4.59	2.48	35.1	Seriously rotted.

considered as having no special significance beyond the fact that little discrimination can be made between them or between the different species represented.

For the six months' period the average loss in the sapwood of 21 species (exclusive of white cedar) was 48 per cent., while the average loss in the heartwood of hemlocks, spruces and firs was 49.6 per cent. These figures show that decay progressed at the same rate during the second three months as during the first three (allowing one month after inoculation for the fungus to become uniformly distributed throughout the flasks).

Sapwood tests over a 12 months' interval resulted in complete decay for all species (23) which were not too wet. The average loss for all was 68.2 per cent. and for hemlocks, spruces and firs 68.4 per cent. The corresponding loss in the heartwood of the latter genera (exclusive of Douglas fir) was 65.9 per cent. In all of these specimens the wood was so thoroughly rotted that it could be pulverized between the fingers.

TABLE VII

PER CENT. LOSS IN DRY WEIGHT FOR THE DIFFERENT TEST PERIODS

[An asterisk (*) denotes that the blocks became too wet for a fair test.]

Kind of Wood	Sapwood			Heartwood		
	4 Months	6 Months	12 Months	4 Months	6 Months	12 Months
Hemlocks	23.3	—	68.9	29.2	53.8	61.7
Spruces	27.5	48.7	69.7	36.2	49.8	67.1
Firs	23.8	41.5	66.4	38.9	45.1	70.1
White pines	21.9	50.8	66.1	—	—	—
Hard pines	25.1	52.4	69.7	—	—	—
Western yellow pine	24.4	52.5	70.9	17.9	—	55.9
Lodgepole pine	21.0	46.6	67.7	14.7*	—	64.4
Longleaf pine	30.5	56.1	69.4	0.4	—	51.1
Pitch pine	24.3	14.8*	71.4	2.3*	—	10.9*
Norway pine	—	—	—	0 *	—	69.4
Shortleaf pine	25.1	64.7	68.7	7.0	—	20.7
Western white pine	17.2	45.1	61.5	9.7*	—	32.1*
Sugar pine	22.9	54.8	67.8	14.3*	—	57.9
Table mountain pine	8.7*	41.9	70.0	3.6	—	39.6
White pine	25.7	52.4	69.1	1.1*	—	8.8
European larch	10.0*	49.6	70.5	42.2	25.5	42.9
Douglas fir	26.4	48.4	68.5	33.6	—	28.1*
Bigtree	2.8*	37.5	63.0	0.7	—	35.1
Port Orford cedar	19.8	37.9	66.8	1.3*	—	22.6*
White cedar	0 *	10.7	7.7*	0	—	5.4*
Western red cedar	2.3*	59.7	35.9*	0.4*	—	21.3*
California juniper	28.3	12.0*	37.9*	0	—	3.3
Western juniper	21.7	48.9	16.8*	0.7*	—	15.2*

The 12 months' test on heartwood of the remaining species brings out considerable differences in durability, ranging from 3.3 per cent. loss in California juniper to 69.4 per cent. in Norway pine. White pine was affected but little (8.8 per cent.), while sugar pine was seriously rotted (57.9 per cent.). Lodgepole pine (64.4 per cent.) fell in the class with hemlocks, spruces and firs. The specimen of longleaf pine, which did not appear very highly resinous, did not prove as resistant (51.1 per cent.) as shortleaf pine (20.7 per cent.), which was of a good grade. Table mountain pine, a close relative of the shortleaf, and apparently quite resinous, lost 39.6 per cent. The durability of bigtree wood (35.1 per cent.) did not fully meet expectations. Other interesting features of the tests were as follows:

The sapwood of white cedar proved highly durable, standing out in marked contrast to that of any other species tested.

The sapwood of Port Orford cedar, bigtree, western red cedar, junipers, and hard pines was very susceptible to decay.

The sapwood of Douglas fir fell in the same class as the true spruces, firs, and hemlocks.

The heavy, hard, yellowish heartwood of California juniper was considerably more durable than the softer, reddish heartwood of western juniper.

Further tests on the heartwood of such species as Port Orford cedar, white cedar, western red cedar, western juniper, Douglas fir, pitch pine, and western white pine are necessary before safe comparisons can be made.

The common names for woods listed above are, for the most part, those recommended by G. B. Sudworth of the United States Forest Service. The corresponding botanical names, source and laboratory number are as follows:

White cedar,	*Thuja occidentalis* L.	Wis.	124
Western red cedar,	*Thuja plicata* Don.	Mont.	224–8
Bigtree,	*Sequoia washingtoniana* (Winsl.) Sudw.	Cal.	40
Alpine fir,	*Abies lasiocarpa* (Hook.) Nutt.	Colo.	15–1
Grand "	*Abies grandis* Lindl.	Mont.	224–16 10–9–30
Noble "	*Abies nobilis* Lindl.	Wash.	77
Eastern hemlock,	*Tsuga canadensis* (L.) Carr.	Tenn.	226–9
Western "	*Tsuga heterophylla* (Raf.) Sarg.	Mont.	136
Mountain "	*Tsuga mertensiana* (Bong.) Carr.	Wash.	13–4
California juniper,	*Juniperus californica* Carr.	Cal.	142
Western "	*Juniperus occidentalis* Hook.	Cal.	121
European larch,	*Larix europaea* D. C.	Wis.	126
Western yellow pine,	*Pinus ponderosa* Laws.	Mont.	224–21
Lodgepole "	*Pinus contorta* Loud.	Mont.	10–2
Longleaf "	*Pinus palustris* Mill.	La.	176–38
Pitch "	*Pinus rigida* Mill.	Tenn.	136
Norway "	*Pinus resinosa* Ait.	Wis.	127
Shortleaf "	*Pinus echinata* Mill.	Ark.	203–1
Western white "	*Pinus monticola* Dougl.	Mont.	224–2
Sugar "	*Pinus lambertiana* Dougl.	Cal.	122

Table mountain pine, *Pinus pungens* Michx. f.	Tenn.	226–80
White " *Pinus strobus* L.	Wis.	120
Port Orford cedar, *Chamaecyparis lawsoniana* (Murr.) Parl.	Oreg.	98
Douglas fir, *Pseudotsuga taxifolia* (Lam.) Britt.	Cal.	38–6–2
Engelmann spruce, *Picea engelmanni* Engelm.	Colo.	15–25
Red " *Picea rubens* Sarg.	Tenn.	226–84
Sitka " *Picea sitchensis* (Bong.) Trautv. & Mayer	Wash.	13–7
White " *Picea canadensis* (Mill.) B. S. P.	N. H.	60

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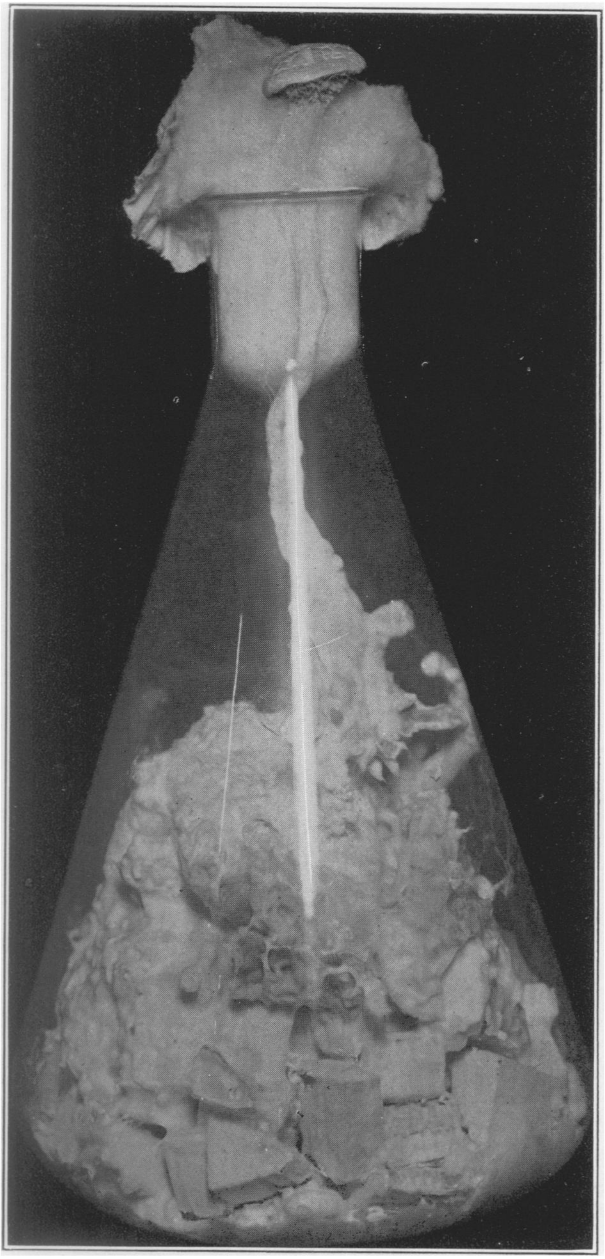

TEST FLASK WITH SPORULATING FRUIT-BODY OF *LENTINUS LEPIDEUS* GROWING UP THROUGH COTTON PLUG AND PUSHING OFF THE MUSLIN CAP. CULTURE ABOUT 9 MONTHS OLD